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Electric Motor

Sub B1

The invention relates to an electric motor, preferably of the three-phase current design.

Electric motors are being used more and more in automotive engineering. Systems that handle the power exchange on the machine voltage level are known, such as the ISAD system (integrated starter-alternator-damper system).

Furthermore, electrically operated turbochargers are known, in which the power exchange also takes place on the machine voltage level. Thereby, the turbocharger capacity is derived entirely from the machine's mains.

Sub B2

The aim of this invention is to create an electric motor that can be used especially in automotive engineering and that provides sufficient electric power or different levels of voltage for the supply of two different mains, especially for the turbocharger.

The problem is solved by this invention. The electric motor according to this invention is characterized by the fact that a first electric motor is provided, which is mechanically connected via the rotor thereof to a rotating shaft of an engine, especially of an internal combustion engine, that in addition at least one second electric motor is provided, that the second electric motor is mechanically coupled via the rotor thereof to a rotating part of a mechanical aggregate, especially to a turbo-engine, and that the first electric motor is electrically coupled to at least the second electric motor in order to exchange electric power at a freely selectable voltage level. With this invention, it is possible for the first time to create a separate, autarkic, internal electric circuit that is independent from the voltage level of the machine's mains. With this, the motor according to the invention and the electronic power circuits can be designed with optimal operating voltages. It is also known that it is usually more advantageous to transport electric power at higher voltages than those currently common in the machine's mains.

This internal electrical component is connected with the first motor through electronic power components such as diodes and transistors and via circuits in accordance with the state of the art, in order to design the internal electrical component in terms of its electric ratios, such as voltages and currents and their time curves.

The first motor can supply and discharge mechanical torque via the combustion engine, so that the first motor can work as a generator when power is consumed, and it discharges this energy to the internal electrical part in the form of electric power. If the first motor draws electric power from the internal electric part, it works as a motor and can use this torque e.g. to start the combustion engine or to support or optimise its operation.

In a special feature of the invention, the first electric motor is mechanically connected via the rotor thereof to a rotating shaft or to the shaft of a combustion engine mechanically connected to the rotating shaft. As a result, the mechanical torque between the first electric motor and the combustion engine can easily be exchanged.

In accordance with one embodiment of the invention, the first electric motor is mechanically connected to the combustion engine via a gearbox. This design solution also improves the torque at low revs in an electrically driven turbocharger.

In accordance with another embodiment of the invention, the first electric motor is a part of the combustion engine, e.g. the rotor in the first electric motor is integrated in the flywheel of the combustion engine. The advantage of this design solution lies mainly in the fact that the entire arrangement can be produced in a relatively compact manner.

In accordance with a special feature of the invention, the first electric motor is connected to at least one external electric circuit, preferably a machine's mains. This second electric coupling is connected to the machine's mains via an electronic voltage adjustment circuit in accordance with the state of the art. As a result, power can be

exchanged between the internal electric part and the machine's mains. Thus, the first electric motor in accordance with the invention can be operated as a starter in one power direction and as a machine's mains charging device in the other direction.

In accordance with a further embodiment of the invention, the first and second electric motors are mounted in a casing. With this embodiment, it is possible to produce an electric drive system that can be manufactured and used economically. The advantage of this invention is the fact that, unlike the known electromagnetic drives or purely mechanical drives, such as gears in which two different, usually independent speeds are required, major parts such as the casing elements, parts of the controls, can be spared. In addition, the well-known local EMC problems in the casing can be solved and do not penetrate into the surroundings.

In accordance with a further embodiment of the invention, the first and/or second electric motor(s) is/are designed as asynchronous, synchronous or reluctance motor. Thus, the optimal motor can be chosen for each individual application.
In accordance with a further feature of the invention, the first and second electric motors have rotors with the same axis of rotation. Especially in automotive engineering it is an advantage if there is only one axis of rotation for a mechanic-electric-mechanic coupling.

In accordance with a special embodiment of the invention, one of the two motors is designed as an inner rotor and the other motor as an outer rotor. This embodiment of the invention also allows a compact motor design.

In accordance with a further feature of the invention, the two electric motors have one mutual stator plate package. In this embodiment, a stator with at least one stator coil and at least two rotors can be provided in one casing. The rotors are mechanically separated, and each rotor has electromagnetic interaction with the electromagnetically active stator, whereby the rotor speeds may be the same or different.

Sub B3

In accordance with a further embodiment of the invention, the components for

electric power exchange between the electric motors and/or an external electric circuit are mounted in the casing of at least one electric motor. This embodiment serves primarily to create a compact electric motor for automotive engineering.

In a further embodiment of the invention, the casing of at least one electric motor has a liquid cooling system. As a result, the frictional heat of the coils and also of the electronic power elements, which may occur due to the known problems with the high currents in the motor, can be discharged optimally.

In accordance with another feature of the invention, a mains connection with direct, alternating or three-phase current can be derived from the electric circuit connecting the two electric motors. In this embodiment, an additional three-phase, alternating or direct current network can be provided by the internal electric circuit. For example, a strong 230 V supply or 3x400 V supply can be decoupled, whereby the frequency can be specified either internally or externally. Thus, the machine's mains and the aggregates connected to it are connected to this supply in terms of power via the internal electric circuit.
As a result, the combustion engine can be started from the power supply without requiring the machine's mains, for example, or vice versa the combustion engine can support or charge an existing supply. It is also possible to charge the machine's mains battery from the supply in a simple manner.

In accordance with a special feature of the invention, the stator of at least one electric motor has at least two winding systems, preferably separated galvanically within the motor, which are mechanically coupled with the motor's main current. With this embodiment of the invention, it is possible to create two autarkic electric circuits with independent voltage levels. Another advantage of this invention is the fact that electromagnetic or EMC interference from switching in one winding system can be suppressed in another winding system. Moreover, the individual winding systems can work advantageously at different voltage levels, especially galvanically separate ones. Specific galvanic separation and/or a transformer for voltage adjustment between the two

electric circuits involved is no longer required.

In accordance with a special feature of the invention, at least two winding systems are connected via separate electronic power switches with the relevant, preferably galvanically separated power circuits. This offers the advantage that for example a mains supply, especially a machine's mains can be operated and controlled separately from another mains supply.

In accordance with a further embodiment of the invention, at least one winding system is connected via a rectifier bridge with a direct current or battery-fed mains, preferably a machine's mains, for power exchange in one direction. With this embodiment, more economic, or even cheaper electronic power components can be used for charging.

In accordance with a further feature of the invention, at least one winding system is connected via a transistor bridge with a direct current or battery-fed mains, preferably a machine's mains, for power exchange in both directions. This offers the advantage that a separate starter is not required, or power is drawn from one mains, preferably the machine's mains, and fed into the other mains.

In accordance with a special feature of the invention, the motor with at least one of the winding systems can be operated as a generator for charging the connected machine's mains, and also as a motor, preferably as a starter for a mechanically coupled combustion engine. This embodiment also offers the advantage that the starter, but also the generator can be eliminated in the design.

In accordance with a further embodiment of the design, galvanically separated electric power exchange via the at least two winding systems is possible between the electric circuits connected to the winding systems. This allows the advantageous separation of the machine's mains from the second mains, which may well have a higher voltage.

In accordance with a further embodiment of the invention, the winding systems controlled via the electronically controlled switches take over the control of the electric parameters from winding systems coupled via non-controllable electronic power elements, preferably diodes. Thereby it is advantageous that for the control of the charging process no separate controllable elements are required and instead the controllable elements of the second mains can be used.

In accordance with a further feature of the invention, each winding system – galvanically independent from the other winding system – is connected with electromechanical function groups on generally different voltage levels. Thus, the electromechanical function groups, e.g. an electrically operated oil pump or water pump, or an electromagnetically operated valve control for in- and output valves or motor valves, or an electrically operated ventilator can be operated independent of the power limitation of the direct current or the battery at an advantageous voltage and/or current level.

In accordance with a special embodiment of the invention, an electromagnetic power exchange between the winding systems independent of rotor rotation according to the transformer principle is possible through close magnetic coupling of the winding systems. This offers the advantage that even when the rotor is stationary a power transfer to the relatively closely coupled other winding system is possible via a time-variable voltage through suitable electronic actuators on one winding system.

In accordance with a further feature of the invention, a slight electromagnetic influence on the winding systems results from weak magnetic coupling of the winding systems. This offers the advantage that electromagnetic interference due to switching processes in one winding system hardly takes effect in the other winding system.

In accordance with a further embodiment of the invention, a freely selectable electromagnetic power exchange between the winding systems and the rotor shaft can be achieved by controlling the electromagnetic parameters, preferably the currents and flux

linking, of at least one winding system. This embodiment offers the advantage that mechanical and electric energy is provided in accordance with the current, optimal strategy.

In accordance with a further embodiment of the invention, a first and second electric motor is mounted in a casing. With this embodiment, it is possible to produce an electric drive system that can be manufactured and used economically. The advantage of this invention is the fact that, unlike the known electromagnetic drives or purely mechanical drives, such as gears in which two different, usually independent speeds are required, major parts such as the casing elements, parts of the controls, can be spared. In addition, the well-known local EMC problems in the casing can be solved and do not penetrate into the surroundings.

In accordance with a further embodiment of the invention, the first and/or second electric motor(s) is/are designed as asynchronous, synchronous or reluctance motor. Thus, the optimal motor can be chosen for each individual application.

Sub B4

In accordance with a further feature of the invention, the first and second electric motors have rotors with the same axis of rotation. Especially in automotive engineering it is an advantage if there is only one axis of rotation for a mechanic-electric-mechanic coupling.

The invention is explained in more detail based on the design examples illustrated in the figure.

Fig. 1 shows an electric motor with rotors with the same axis of rotation,

Fig. 2 a basic sketch of the electrical circuit of the motor,

Fig. 3 the electric motor with the electronic elements,

Fig. 4 and 5 an embodiment of the electric motor,

Fig. 6 a basic sketch of an electrical circuit of the motor, and

Fig. 7 an interconnection between a generator and a compressor engine via a converter.

By way of introduction, it is noted that in the described embodiment the same parts and the same states are allocated the same reference numbers and the same component names, whereby the disclosures contained throughout the description can be applied by analogy to the same parts and the same states with the same reference numbers or same component names. Furthermore, position details given in the description, e.g. top, bottom, side, etc., relate to the figure being described and illustrated at the time and with a change of position should be transferred accordingly to the new position.

Moreover, individual features or combinations of features from the different embodiments illustrated can represent independent solutions according to the invention in themselves. The relevant tasks and solutions according to the invention are shown in the detailed descriptions of these figures.

Sub B5

Basically, various design variations for such electric motors are possible. Fig. 1 shows a a first electric motor 10 with one stator 1, which has one winding 2. In the cylindrical motor array, one winding 2 is on the inside of the stator 1 or the stator bore, and can be designed as a groove or air-gap winding. The second electric motor 11 has one winding 3 on the outside of the stator 4 as a groove or air-gap winding, whereby winding 2 interacts with a rotor 5 designed as an inner rotor, and winding 3 interacts with a rotor 6 designed as an outer rotor. The rotors 5, 6 can be designed with permanent magnet excitation, as cage rotors, with a reluctance structure, etc. The two rotors 5, 6 are mounted mechanically on one suitable bearing 7, 8 each according to the state of the art in the casing 9.

As already mentioned, the main application for such an electric motor 10, 11 is

in the field of automotive engineering, whereby it can fulfil several functions. The first electric motor 10 is mechanically coupled with the combustion engine, e.g. via a gearbox with a rotating shaft, or the first motor 10 with its rotor 5 is located directly on an existing element of the combustion engine, such as e.g. the gear flywheel or an existing drive wheel, or it is structurally integrated with this component. This first motor 10 can thus supply and discharge mechanical torque with the combustion engine, so that the first motor 10 can work as a generator when power is consumed, and it discharges this energy to the internal electrical part in the form of electric power. If the first motor 10 draws electric power from the internal electric part, it works as a motor and can use this torque to start the combustion engine or to support or optimise its operation.

In accordance with Fig. 2, the first electric motor 10 and the second electric motor 11 are each connected to a control or power component 12, 13. For the exchange of electric power at freely selectable voltage levels, the two control and power components 12, 13, which also perform the electronic power conversion, are connected to each other. This internal electric circuit is connected with the first motor through electronic power components, such as diodes and transistors and via circuits in accordance with the state of the art, in order to design the internal electrical component in terms of its electric parameters, such as voltages and currents and their time curves. An important feature of this internal electric circuit and thus of the voltage level of the first motor is the independence of the voltage level from an external electric circuit, the so-called machine's mains 14. Thus, the motors in accordance with the invention and the electronic power circuits can be designed with optimal operating voltages. It is known that it is usually more advantageous to transport electric power at higher voltages than those currently common in the machine's mains.

This external machine's mains 14 is connected to the internal electric circuit via an additional control or power component 15.

This also offers a major advantage of this arrangement, since the mechanical power exchange between the combustion engine and one or more additional aggregates, such as turbochargers, pumps, ventilators, compressors, etc., can be provided without

using the machine's mains. In addition to the optimal voltage level, the arrangement also offers significantly improved EMC properties, since with simple measures in accordance with the state of the art the EMV interference is not able to penetrate the machine's mains 14 or generally the environment of the aggregate and only has to be controlled within the aggregate. Moreover, with this arrangement it is possible to transfer significantly more power for the supply of secondary aggregates independent of the speed than is possible via the machine's mains.
From this internal electric component, the voltage of which can be adjusted to optimal operation of the array constantly, provided the electronic power elements allow this, one or preferably two or more electric power exchange couplings branch off.

The first electric coupling goes via the electronic power elements to the electric connection of the second motor 11, which can transform electric power at a speed level basically independent of the first motor 10 into mechanical power. In the preferred variant of this array, this mechanical power serves to operate a turbo engine, such as a turbocharger, thus making the advantage of turbo engine operation independent of the combustion engine speed possible. Compared with the known electrically operated turbochargers, this array also offers the major advantage that the turbocharger power is not necessarily drawn entirely from the machine's mains 14, but is exchanged completely or partly with the combustion engine via the first motor 10. This means that there is considerably less stress on the machine's mains, and it allows a power exchange on a more favourable electric voltage level, whereby the wiring and the electronic power components can be designed more favourably. The power exchange can be bi-directional. In the same way, further electric motors as a part of the invention can be coupled to the internal electric part for the operation of additional aggregates, such as e.g. water pumps, ventilators, compressors, etc.

The second electric coupling is connected to the machine's mains via an electronic voltage adjustment circuit in accordance with the state of the art. As a result, power can be exchanged between the internal electric part and the machine's mains 14. Thus, the first electric motor 10 can be operated as a starter in one power direction and

as a machine's mains charging device in the other direction. The major advantage of this operating mode lies in the fact that a separate starter and a separate generator are not required, since these functions are provided by the array. A major advantage over known arrays lies in the fact that the starter can now be designed and operated as a motor with optimal voltage level, so that the known problems with high currents in the motor and also in the electronic power elements connected to the motor phases are avoided.

Furthermore, the second motor 11 can also be operated via the machine's mains 14 independent of the combustion engine, e.g. even when it is switched off. This means that the turbocharger can, for example, be started while the combustion engine is off, thus allowing a better starting process. Compared with known solutions, this solution offers the advantage that the second motor and the power electronics on the motor side can be designed and operated at an optimal voltage level.

In a further embodiment, an additional three-phase, alternating or direct current network can be provided by the internal electric circuit. For example, a strong 230 V supply or 3x400 V supply can be decoupled, whereby the frequency can be specified either internally or externally. Thus, the machine's mains 14 and the aggregates connected to it are connected to this supply in terms of power via the internal electric circuit.

As a result, the combustion engine can be started from the power supply without requiring the machine's mains, for example, or vice versa the combustion engine can support or charge an existing supply. It is also possible to charge the machine's mains battery from the supply in a simple manner.
In accordance with Fig. 3, the first electric motor 10 and the second electric motor 11 are mounted in the casing 9.

For cooling, the casing 9 can have cooling channels 16. In the area of these well-cooled casing components, an electronic power and control circuit including electric, magnetic and mechanical components, such as semiconductors 19, capacitors 18,

throttles, relays or the like and any required carrier materials 17 can be arranged in order to realize the functions in accordance with the elements, such as the control and power component 12, 13, 15 in Fig. 2, advantageously.

A further embodiment of the electric motor is shown in Figures 4 and 5. Thereby, the two electric motors 10, 11 can be arranged on top of each other, and the rotor output can be provided on the left and/or right of each motor. Thereby, the electronic component 20 can also be integrated in this motor casing.

Fig. 6 shows a three-phase electric motor, whereby this electric motor may be the first or the second electric motor. The rotor of the first electric motor is, for example, mechanically connected via a rotating shaft to the combustion engine. The rotor of the second electric motor is coupled with a rotating component, for example a turbo engine. For the exchange of electric power at a freely selectable voltage level, the first electric motor is electrically connected to the second electric motor.

The stator 21 of at least one of the two electric motors has at least two winding systems 22 and 23. The two winding systems 22, 23 are preferably galvanically separated in the electric motor and magnetically coupled with the main flux of the motor. Due to the galvanic separation, i.e. each winding system 22, 23 lies preferably in its own grooves, EMC interference from switching in one winding system 22, 23 can be suppressed.

The two winding systems 22, 23 are connected via separate electronic power circuits 24, 25 to individual power circuits which are also preferably galvanically separated. Thus, the winding system 22 can be connected via the electronic power circuit 24, for example a rectifier bridge or a transistor bridge with a direct current or battery-fed mains, preferably with the machine's mains 26, for power exchange in one or both directions. Naturally, this winding system 22 could also be operated as a motor, preferably as the starter for a combustion engine.

Via the electronic power circuit 25, a mains 27 can be supplied. Equally, this electronic power circuit 25 can also be electrically connected via the internal mains to an electronic power module 28 for the second electric motor 29.

Each winding system 22, 23 is connected, galvanically independent of the other winding system 22, 23, with electromechanical function groups on generally different voltage levels. Thus, the electromechanical function groups, e.g. an electrically operated oil pump or water pump, or an electromagnetically operated valve control for in- and output valves or motor valves, or an electrically operated ventilator can be operated independent of the power limitation of the direct current or the battery at an advantageous voltage and/or current level.

The winding systems 22, 23 can have a weak magnetic coupling, for example if the winding systems are located in different grooves, or even a close magnetic coupling, if both winding systems 22, 23 are located in one groove.

Fig. 7 shows a generator, for example as the first electric motor 10, and a compressor engine as the second electric motor 11. The two electric motors are electrically connected via a generator inverter 32 and a compressor motor inverter 33. Uzk refers to the intermediate circuit voltage.

The generator is connected via its rotor to a motor, in particular a combustion engine, through a gearbox 35. The compressor motor 31 is connected via its rotor to a turbo engine 34. A winding system 22, 23 is connected via an electronic power circuit 4 to a machine's mains 6, whereby the winding systems 22, 23 can be separated galvanically.

Thereby, the first and the second electric motor can be mounted in a casing. Equally, the first and the second motor may have rotors with the same axis of rotation.

For form's sake, it is noted that for a better understanding of the invention the

components are illustrated partly untrue to scale and/or are enlarged and/or made smaller.

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